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Design Simulation and Production of 2-Stage Reduction Gearbox for All Terrain Vehicles

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Abstract – *In general all-terrain vehicle (ATV) includes an engine of horizontal shaft type, which has a power output shaft extending horizontally left hand side of the engine. The engine power output shaft carries complete pulley assembly of a belt-type continuously variable transmission (CVT) and second pulley assembly is carried by an inclining extending shaft supported in a bearing assembly secured to the engine. The horizontally extending shaft carries shaft power vertically to a level below the engine at which a gearbox unit of 2-Stage reduction. This unit provides us selection of Constant meshing gear assembly and in second position second pulley assembly is in inclined position behind the engine setup. Gears in the transmission are really just multipliers in the rational velocity equation. In these report we describe the two types of engine and transmission with CVT positions to get the higher acceleration by overcoming the overall weight of the assembly and it also represents the graph values, calculation and iteration values, material and properties selection with machining processes.*

Key Words: Briggs and Stratton OHV engine, Continuously Variable Transmission (CVT), 2-Stage Reduction Gearbox,

1. INTRODUCTION

This report represents redesign of powertrain system for all terrain vehicles. In first Consideration the Engine and Gear box connected in Vertical position via CVT belt. Basically the purpose of the drive train is to transmit shaft power and torque of the Briggs and Stratton OHV engine to the rear wheels of the car. The 10 HP engine produces 14 ft-lb of torque at 3800 rpm. High speed was desired for the acceleration and speed trials while high torque was preferred for traction pulling and climbing.

The objective of the report is to use different assembly of 2-Stage reduction Gearbox with CVT assembly in vertical and inclined positions.

- To achieve minimum acceleration timing.
- To reduced the maximum gradability of ATV vehicle.
- To overcome the weight factor.
- To reduced the Gear Ratio.
- To achieve aggressive acceleration.

1.1 Vertical Setup

In this setup the Engine and Gearbox are connected via CVT in Vertical position.

Fig -1: Vertical CVT Assembly

1.2 Inclined Setup

In this setup the Engine and Gearbox are connected via CVT in Inclined position.

Fig -2: Inclined CVT Assembly

2. ENGINE

In these report we consider the information and specification of the Briggs and Stratton OHV engine to the rear wheels of the all terrain vehicle.

Table -1: Engine Specifications

Max Torque	19.6 N-m
Engine displacement	305cc
Max. Power	10 Hp@2800rpm
No of cylinders	Single
Engine Configuration	Horizontal Shaft
Engine Technology	OHV
Shaft rotation	CCW
Length(in)	12.3
Width(in)	15.4
Height(in)	16.4
Weight(Kg)	22.68
Bore(in)	3.12
Stroke(in)	2.44
Engine Fuel	Gasoline / Petrol

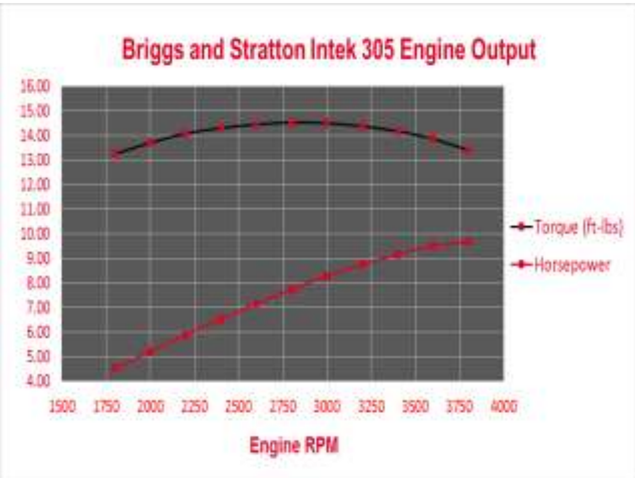

Fig -3: Engine Output Graph

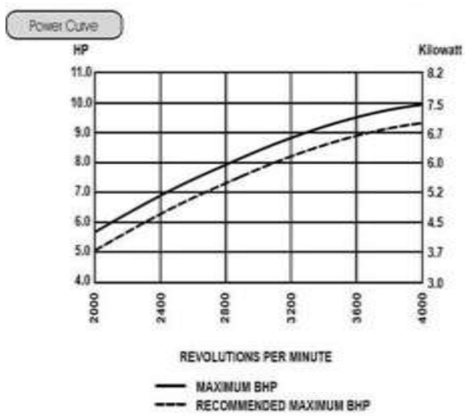

Fig -4: Power Curve Graph

3. CONTINUOUSLY VARIABLE TRANSMISSION (CVT)

A continuous variable transmission is an automatic transmission that can change seamlessly through an indefinite number of gear ratio between maximum and minimum values. The flexibility of CVT allow input shaft to maintain a constant angular velocity when power is more important than economy the ratio of CVT can be change to allow the engine to turn at an RPM at which it produces greatest power. This is typically higher than the RPM at which it produces greatest power. This is typically higher than the RPM that achieves peak efficiency.

The conventional transmission commonly functions within a single engine power band and allows the engine speed to fluctuate within this power band as each gear exchange is made. In this way, the conventional transmission increases vehicle speed while the engine operates in the same power band for each gear ratio.

Parts of CVT:

- Driving pulley
- Driven pulley
- V Belt

Fig -5: CVT Components

3.1 Driving Pulley

Driving Pulley has one main purpose to control the engine speed in all shift ratios. The mechanism works with pressure spring and centrifugal force and working against each other to give the engagement speed. The third component including driven pulley is Flyweights and it helps to overcome the driven pulley pressure to maintain the shift speed, by modifying the flyweights or changing springs we obtained the desired Engine Speed.

Fig -6: Driving Pulley

3.2 Driven Pulley

The main purpose of Driven pulley is to provide enough side pressure on the belt to allow the power to be transmitted to the 2-Stage constant reduction Gearbox. Side pressure is therefore an important factor to determine overall efficiency of drive system. The loss is due to the belt friction heating up to the Sheaves. Setting up the Driven pulley, we are interested in getting enough pressure to prevent belt from slipping and making the transmission back shift when it hits the hill or deep snow. . The only reason to tighten up the driven pulley, if the belt is not spinning, is to improve the back-shifting. Tuning on the rear by tightening up the spring also causes you to lose some efficiency.

Fig -7: Exploded Veiw of Driven Pulley

3.3 V Belt

The v belts transmit over 300HP with efficiency and consistency the development of drive belts has been improving in the last 20 years. The earlier belts were made up with fibreglass cords which were stiff and had poor adhesion with rubber. The new material called Kevlar or fibre "B" started to make inroads. Engineers found that 45 gauge Kevlar cord was just strong as a 90 gauge fibre glass cord and gave the belts much more flexibility. Belt loss is influenced by the factors like turning radius, belt speed, belt tension and friction loss. The tighter the belt has to run, higher the loss of power.

Fig -8: V Belt

3.4 Flyweights

All shift force is generated by the flyweight system. The flyweight force first works against the pressure spring, and then works to overcome the belt forces from the driven pulley. To keep the engine on power curve, the flyweight force has to match the driven belt pressure curve all the way through the shift range from low ratio to overdrive. If it does not match the driven belt pressure the engine speed will change until it does, but by then we may be off the power curve. The tuner's job is first to match the shift force from the flyweights to get a straight shift, and then to get a good engagement speed in several ways.

The heavier the weight more force they produced, grinding the weight results.

1) Effect on shift force.
2) Shift of centre of gravity and hence centrifugal force is also affected.

Fig -9: Flyweight

3.5 Compression spring

Engagement speed is determined by the amount of pretension of the spring has been compressed to when installed in the pulley. While the pretension determines the engagement speed, the spring rate has an influence on shift characteristics. The side force on the belt is the result of subtracting the spring force from the flyweight force as they work against each other.

3.6 Torsion spring

Some initial pressure is needed on the belt before the torque feed-back can begin to increase the belt pressure. The spring primarily works in torsion although a small amount of side pressure is also present. Usually numbers of holes are available on ramp to adjust the pretension of the spring. The spring tension is measured experimentally. Spring tension is important for both initial belt pressure and back-shifting. The higher the tension, quicker the backshift. Springs with different rates are available, and springs with higher rates are used when more pretension is required for higher horsepower engines.

Fig -10: Torsion Spring

3.7 Working Methodology

The type of CVT considered here is V-Belt rubber type. The input (Engine) is to the primary sheave while the output is from the secondary sheave. When the speed increases, the flyweights pull the movable sheave in the primary sheave closer. The force provided by the flyweight should be enough to overcome the spring force and the frictional force between belt and the pulley. The secondary pulley consists of a similar arrangement with the movable sheaves actuated by a shift in the primary pulley.

Table -2: CVT Iteration Values

Flyweight (gm)	Pre-Tension (N)	Max. Load (N)	Engagement RPM	Shift RPM
275	850	1200	2315	2920
275	600	900	2152	2656
275	450	950	1900	2750
250	850	1200	2633	3303
250	600	900	2400	3100
250	450	950	2250	3150

4. GEARBOX

In determining the basic overall reduction ratio of the 2-Stage reduction gearbox based on the selection of different set of gear ratios and different assembly positions. We wanted to achieve time of 4-6 second for the acceleration of which the max speed came out to be 60 Km\hr. We perform different set of iteration for following gear ratios

1. Gearbox having reduction gear ratio as 11.36:1 and
2. Gearbox having reduction gear ratio as 9.45:1
3.

This provided us with a max torque at the wheels of 400-600 N-m from a standstill with the initial CVT ratio.

Table -3: Gearbox Iteration Values

GEAR BOX :Two stage reduction		
Gearbox 1	**Parameter**	**Gearbox 2**
11.36	G. R.	9.45
7.5m/s^2	Acc. Time	3.79m/s^2
22 kg	Weight	5.29 kg

Fig -11: Exploded view of Gearbox 1

Fig -12: Exploded view of Gearbox 2

4.1 Iteration Methodology

The first step in designing a gearbox is to finalize the gear ratio at which the gearbox will be operated. This was done in two ways using 'concept of traction and tractive effort' and by 'performance simulation'.

4.1.1 Traction and Tractive Effort

Traction - Traction, or tractive force, is the force used to generate motion between a body and a tangential surface, most generally through the use of dry friction. Traction can also refer to the maximum tractive force between a body and a surface, as limited by available friction.

Tractive Effort - The term tractive effort is often qualified as starting tractive effort, continuous tractive effort and maximum tractive effort, which determines the maximum torque that can be applied before the onset of wheel spin or wheel slip.

The gear ratio must provide sufficient torque to propel the vehicle from static position. Crossing the upper limit of the gear ratio causes the wheels to slip at the same static position while too little gear ratio does not help to drive the vehicle. The engine comes with a 10HP power, 19.2Nm torque and a maximum of 3800rpm. Traction and tractive effort was calculated and iterated for several values as follows:

Traction = (T × G.R.) / r
Where, T – Torque (Nm)
G.R. – Gear ratio
r – Wheel radius (m)
Tractive Effort = µmg
Where, µ - Co-efficient of friction
m – Mass of vehicle (kg)
g – Acceleration due to gravity (m/s^2)

Tractive Effort = Maximum allowable limit of tractive effort

Traction = Tractive Force = Applied force on wheel

If

Traction ≤ Tractive Effort → No wheel spin or slip.

If

Traction > Tractive Effort → Wheel spin or slip will occur.

Table -4: Traction and Tractive Efforts Calculation

Gear ratio	Tractive effort Gearbox 1	Tractive effort Gearbox 2	Traction µ= 0.65	Acc time (sec) T2	Acc time (sec) T1
28	1371.27	1365	1402.83	3.81	7.99
28.2	1714.6	1378.16	1402.83	3.79	6.46
29	1903.88	1413.75	1402.83	3.7	5.26

4.2 Analysis Simulation:

The results are compared with the values in this reports and analytical example is presented to show how the practical graphs can be used. We analyzed gear, shaft and casing for Equivalent Stress Theory and obtain the Factor of safety values. This analysis conform the safety of research and calculation of 2-Stage Reduction Gearbox.

I] Equivalent Stress = 338.95 Mpa; FOS = 2.49

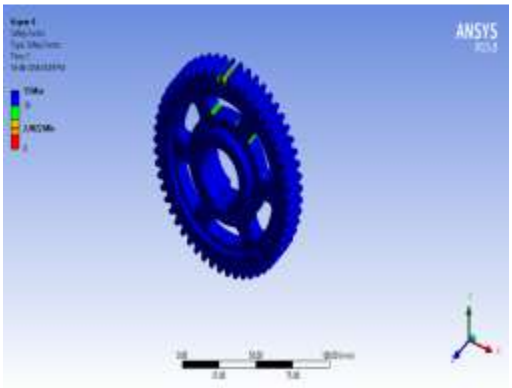

Fig -13: Equivalent Stress Analysis of Gear

II] Equivalent Stress = 243.29 Mpa; FOS = 1.98

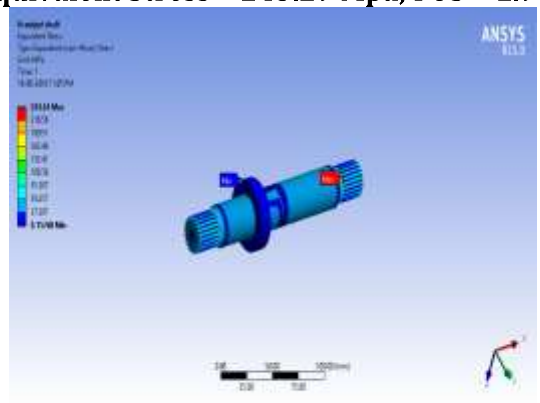

Fig -14: Equivalent Stress Analysis of Shaft

III] Equivalent Stress = 249.97 Mpa; FOS = 1.89

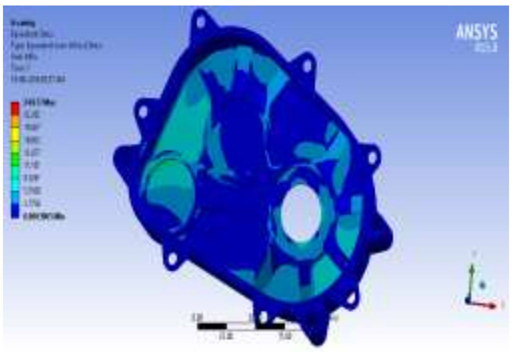

Fig -15: Equivalent Stress Analysis of Casing

4.3 Production:

In this research report we include the information of various materials specification for selecting to overcome weight factor, to increase strength, toughness, reliability, endurance life and fatigue life and having maximum factor of safety. The materials are used as EN19, EN24, EN36, SAE1025, SAE1030, SAE1050, SAE2320 (Drawn 550^{0}C), SAE2330 (Cold Drawn), Heat treated Aluminum Alloys are SAE6061, SAE7075.

$\Delta H_R = \Delta H_P / MW_P * \rho_P / \rho_s * V_F$

Where,
ΔH_R = specific dissolution of precipitate
ΔHp = molar heat of dissolution of precipitate
MWp = molecular weight of precipitate
P_P = density of precipitate
P_s = density of sample
VF = precipitate volume fraction.

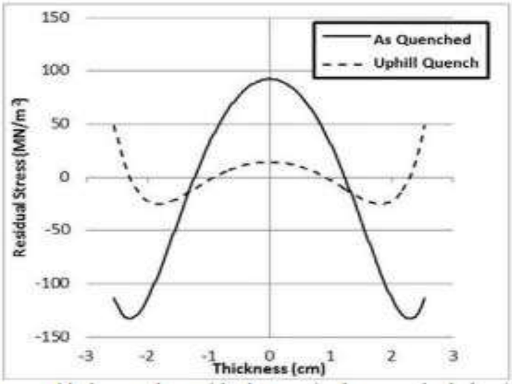

Fig -16: Heat treatment Graph of Al 6061

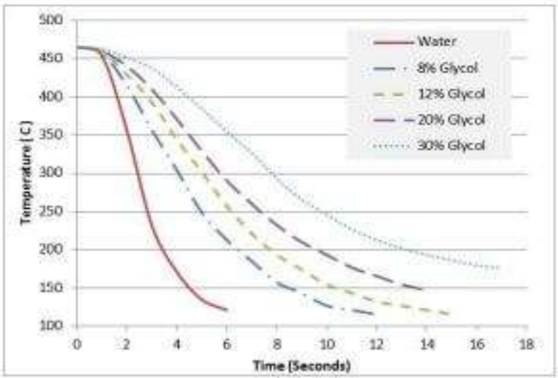

Fig -17: Heat treatment Graph of Al 7075

In general production purposes we have various machining processes and we used specific machining process for particular operation such as Drilling, Shaper, Milling, CNC Lathe, CNC Vertical Lathe, MIG Welding, etc.

Fig -18: CNC Vertical Lathe Machine

Fig -19: CNC Lathe Machine

Fig -20: MIG Welding

Fig -21: Gear Milling Machine

Fig -22: Radial Drilling Machine

Fig -23 Shaper Machine

5. CONCLUSION:

The 2-Stage reduction Gearbox allows the vehicle to stay in the torque and provide high power range from the engine for the trade off to gain fuel economy. It also helps to achieve minimum acceleration timing, aggressive acceleration, gear ratio, maximum gradability of ATV vehicle and to overcome the weight factor. Higher gear ratio has a lower mechanical advantages and it is harder to accelerate the vehicles. Traction should be less than equal to tractive effort or as close as possible in order to meet the transmission efficiently with the corresponding Engine.

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